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Hydrograph Separation in the Wilmot Creek Basin using Recession Factor Analysis and Chemistry of Streamflow

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HYDROGRAPH SEPARATION IN THE WILMOT CREEK BASIN USING RECESSION FACTOR ANALYSIS AND CHEMISTRY OF STREAMFLOW

By

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ONTARIO WATER RESOURCES COMMISSION

Division of Water Resources

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INTRODUCTION

Hydrograph separation using the recession factor analysis and conductance methods was investigated for data from the Wilmot Creek basin.

The empirical approach developed by Barnes (1940), using the recession factor as a means of separating ground-water discharge and surface runoff, was used. The recession curve was developed by plotting the daily average recession discharge versus the average discharge of the preceding day for those days not influenced by rain.

The second relationship defined was the approximate increase in ground-water discharge at the end of given 30-day periods due to recharge by precipitation. This relationship was developed by plotting the monthly increase of ground-water discharge against the corresponding monthly discharge.

The dependence of the concentration of an ion in solution upon the contribution to streamflow from

ground-water discharge and direct surface runoff forms the basis for analysing streamflow by means of water chemistry methods. As the proportion of surface runoff to ground-water discharge changes, the dissolved ion concentration also changes; thus, it is expected that there will be a relationship between streamflow and dissolved ion concentration. In a small stream such as Wilmot Creek, the relationship is relatively simple because stream discharge is derived primarily from rainfall throughout the basin. It should be emphasized, however, that for large streams, this relationship may be more complicated. The drainage basin of a large stream can be large enough so that precipitation often occurs only over a small portion of the basin. As the distance between the storm area and the sampling station increases, the water-level fluctuation in the channel tends to be dampened and the crest of the flood peak becomes less sharp. These factors are presumed to affect the stream water chemistry.

The changes in the ion concentration are believed to be due, to some extent, to seasonal conditions. In summer, soil moisture conditions may be such that much of the rainfall is absorbed to replenish a deficiency in soil

moisture and surface runoff may not be an important factor as a streamflow component. During this period, a high proportion of the stream discharge may be derived almost solely from ground water. In spring, however, the soil may be relatively saturated and a high portion of the streamflow may consist of surface runoff. From this, it is evident that the ion concentration of the water in a stream will change throughout the area and throughout the water year. The above relationships are discussed and examples are given to show the effects in relation to studies conducted in the Wilmot Creek basin which form part of the Ontario Water Resources Commission's contribution to the International Hydrological Decade (IHD) program.

PURPOSE AND SCOPE OF INVESTIGATION

As there is no exact technique available for distinguishing surface runoff from ground-water discharge on a streamflow hydrograph, one can only evaluate present techniques by mutual comparison of the various methods available.

The objectives of the study were to investigate the empirical approach to hydrograph separation, developed by Barnes (1940), and to determine whether or not the ground-water discharge component of streamflow could be determined using the conductance method.

To study the relationship between streamflow chemistry and discharge, it was necessary to select points along Wilmot Creek where precise and continuous streamflow records were available. The Wilmot Creek basin, which is a component of the Bowmanville, Soper and Wilmot creeks representative basin, being studied under the International Hydrological Decade program, fulfilled this requirement. Water samples were taken from three different locations along Wilmot Creek on a monthly basis over a period of about three years. Chemical analyses of the samples were provided by the Ontario Water Resources Commission, Division of Laboratories.

The monthly sampling of streamflow quality was found to be inadequate for some purposes and another sampling program was initiated during the month of April, 1969, for a period of four days. The objectives of that specific study were to evaluate whether or not the ion concentration of stream water is influenced by the individual characteristics of a specific flood and to indicate whether or not the conductance method is a useful tool in hydrograph separation during storm events.

DESCRIPTION OF THE BASIN

Since the quality and quantity of ground-water discharge and surface runoff are related to the geologic and hydraulic characteristics of the hydrologic system through which water flows, a brief description of the basin is given.

Location, Area and Drainage

The Wilmot Creek basin is a component of the Bowmanville, Soper and Wilmot creeks representative drainage basin. The basin is located in southern Ontario on the north side of Lake Ontario in the County of Durham. The area of the basin is approximately 35 square miles and is illustrated in Figure 1. The main branch of the creek rises about four miles north of Leskard at an approximate elevation of 1,050 feet and flows south for a distance of about 17 miles to its outlet into Lake Ontario. It has a total fall of about 755 feet with an average gradient of about 45 feet per mile.

General Geology

The area discussed incorporates parts of three major physiographic divisions as described by Chapman

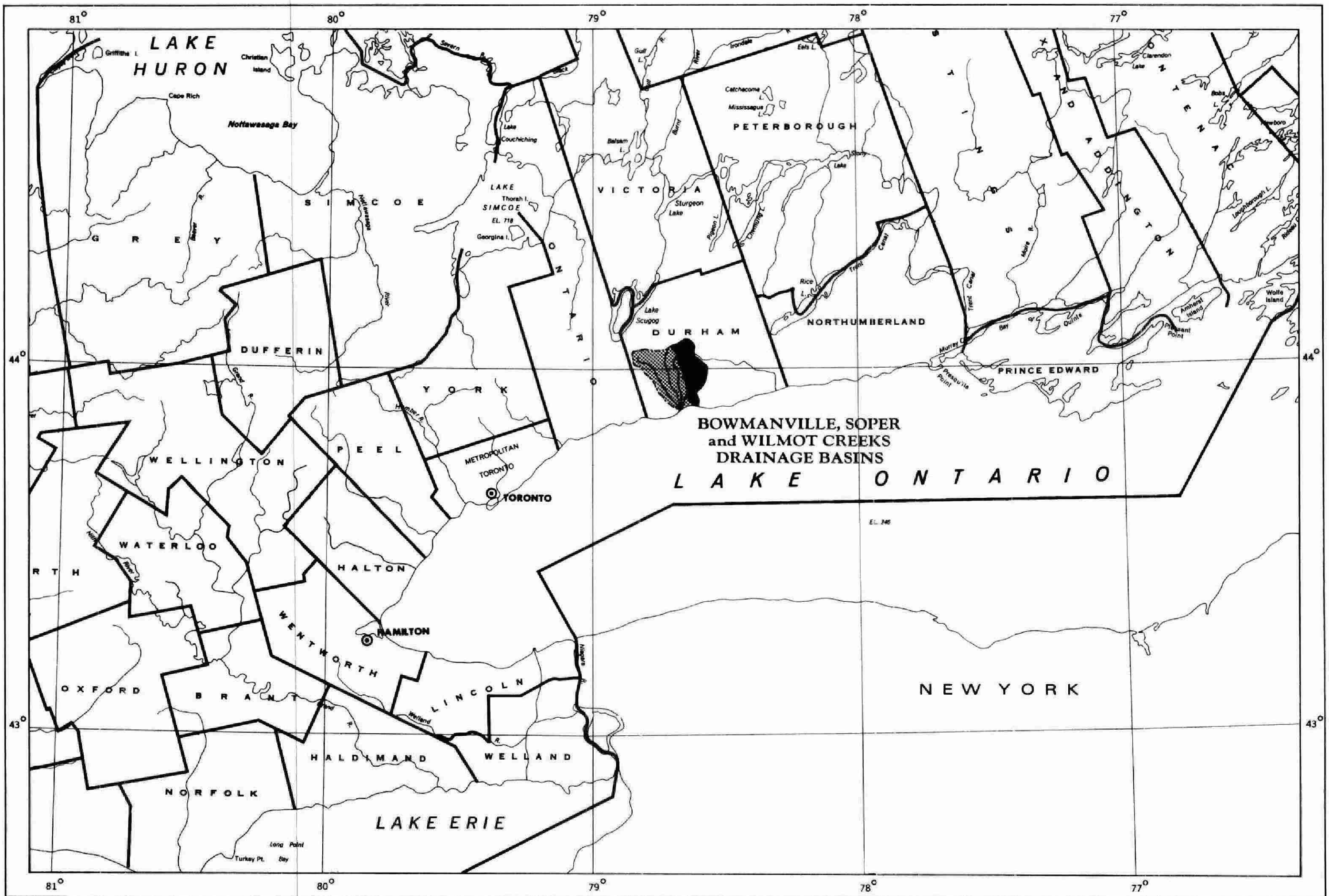


Figure 1. Location of the Bowmanville, Soper and Wilmot creeks basin.

and Putnam (1966): the Oakridges Interlobate Kame Moraine in the north, the Till Plain, and the Lake Iroquois Plain in the south. The major physiographic divisions are illustrated in Figure 2.

Pleistocene deposits from about 25 to 700 feet in thickness overlie limestone bedrock of Ordovician age. The surficial Pleistocene deposits include sands and gravels of the Oakridges Interlobate Kame Moraine, sandy, silty clay tills of the Till Plain, and sands and gravels and lacustrine clays of the Lake Iroquois Plain. The general subsurface stratigraphy of the northern portion of the basin on the Oakridges Kame Moraine indicates approximately 700 feet of overburden overlying the bedrock. The overburden consists of about 200 feet of kame sands and gravels overlying about 500 feet of tills alternating with interstadial sands and gravels. The lower sequence of tills and sands and gravels generally thins to the south across the central portion of the basin where it is overlain by Lake Iroquois shore deposits. South of the shore deposits, north of the present Lake Ontario shoreline, the stratigraphy indicates approximately 10 feet of lacustrine clays, overlying about 45 feet of till, stratified sands and varved clays which in turn overlie the limestone bedrock.

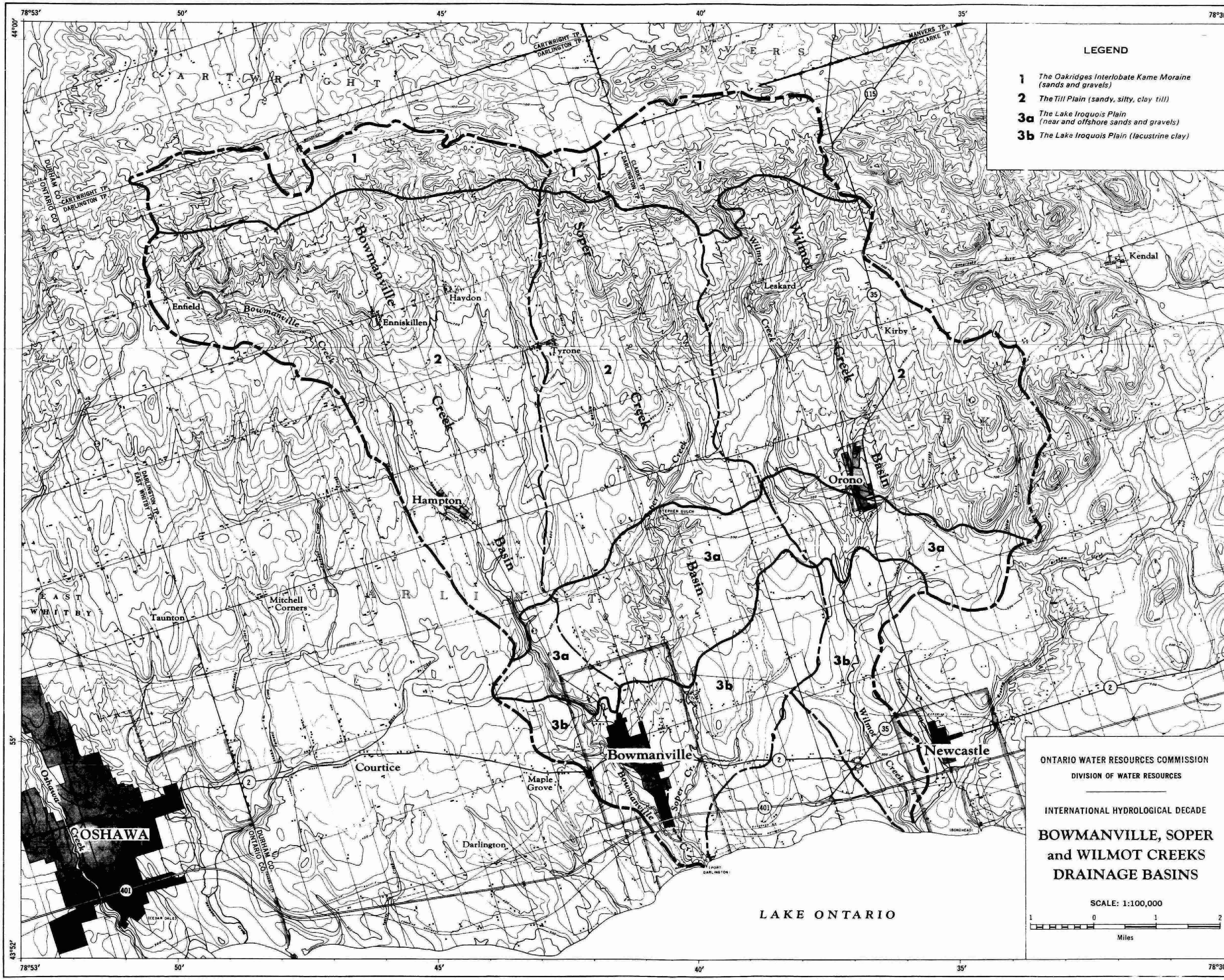


Figure 2. Major physiographic divisions in the Bowmanville, Soper and Wilmot creeks basin.

HYDROGRAPH SEPARATION

Theoretical Discussion

Ground-water discharge or baseflow is a very important component of streamflow which has to be determined in water-balance studies. One of the methods used to evaluate ground-water discharge involves the technique of hydrograph separation into ground-water discharge and surface runoff.

On a streamflow hydrograph for a perennial stream channel, the volume of water represented at any point commonly includes channel interception, overland flow, interflow and ground-water discharge or baseflow. Definitions of these terms vary considerably among glossaries of hydrologic terms. Channel interception is usually defined as the amount of flow derived from precipitation falling, or splashing off nearby vegetation, directly into the stream.

Overland flow is usually defined as the amount of rainfall or snowmelt moving over the surface of the soil to the stream without infiltrating at any point.

Interflow is usually thought of as the rapid movement of some subsurface water to the stream during a specific period, usually termed the direct runoff period.

Direct or surface runoff is the amount of flow resulting directly from a rainfall or snowmelt event; it can be arbitrarily limited in duration and it usually includes all three types of flow just defined. Direct runoff is separated from baseflow by arbitrary methods referred to as hydrograph separation.

Baseflow is thought of as flow from ground-water aquifers and may include bank storage. It can be calculated as the flow that remains after direct runoff has been separated.

Hydrograph separation into the above components is one of the most difficult analysis techniques in use in hydrology. The definitions given above are generally indefinite in space and time. Also, stream channels tend to expand and shrink in different ways during storms and expanding and shrinking of channel areas is usually ignored in reviewing the various parts of direct runoff on the hydrograph.

In a basin which is not homogeneous, water may collect on a relatively impervious area during a storm, but may infiltrate before reaching the streams. In other cases, water will infiltrate, but comes to the surface in an intermittent or ephemeral channel before it flows

to the perennial channel. These different types of flow rarely are discernible on the hydrograph and it is doubtful that any graphical technique alone applied to a hydrograph will allow for a separation of the hydrograph into all the components referred to above.

Various techniques have been developed for separating ground-water discharge and surface runoff. Barnes (1940), described a method of evaluating ground-water discharge by the following equation:

$$Q_t = Q_o K_r^{\,t}$$

where: Q_t = is the flow at time t after the occurrence Q_o;

Q_o = is the flow at any particular time on the recession curve;

K_r = is the recession constant.

Langbein (1940) developed a graphical plot of Q_o versus Q_t to obtain K_r. After evaluating K_r from graphical plots of recession data, a ground-water recession curve is constructed beginning at the point on the receding limb of the storm hydrograph where surface runoff ceases, and continuing backward to a point directly under the crest. From there, a straight line is drawn to the bottom of the rising limb in the manner illustrated

in Figure 3.

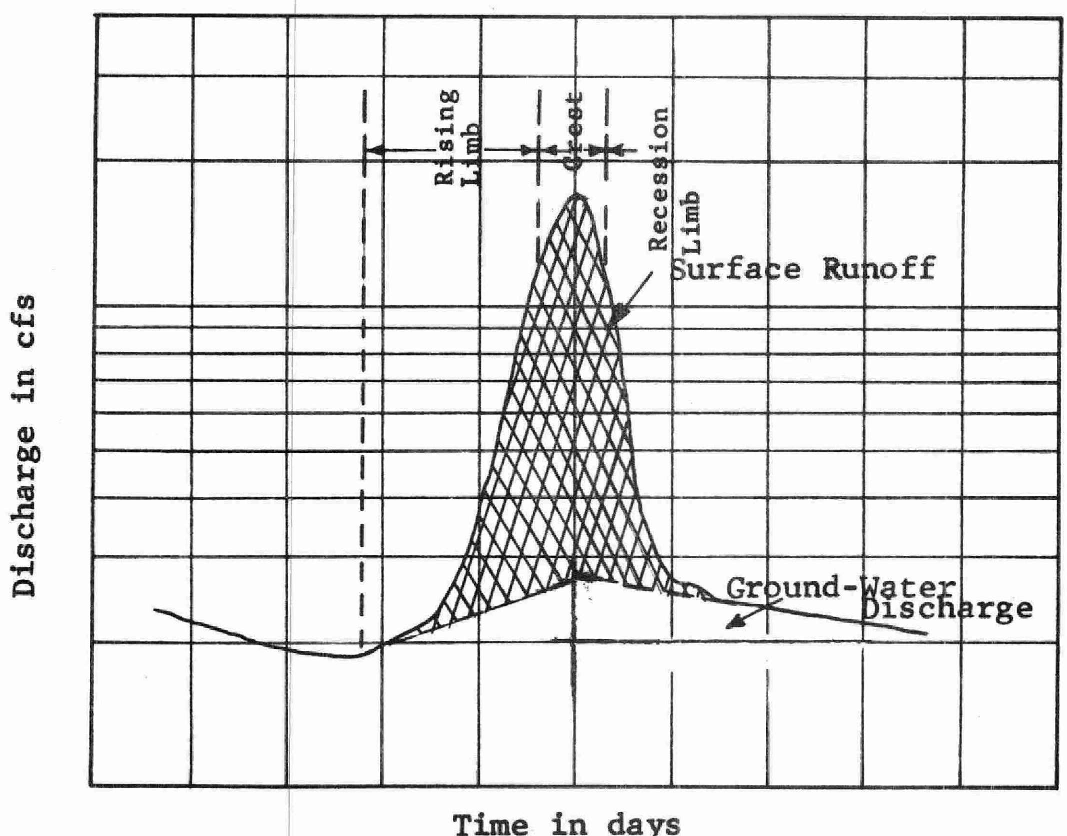


Figure 3. Schematic diagram showing hydrograph separation into surface runoff and ground-water discharge.

Another empirical approach was developed by Kunkle (1965). The approach utilizes the dissolved solids

concentration or conductivity of stream water. Measurements of the conductance or dissolved solids concentration permit ground-water discharge to be determined. The following equation is used:

$$\text{Quality of Streamflow} = \frac{Qor\ (DSor) + Qgw\ (DSgw)}{Q}$$

where: Q = is the total discharge in cubic feet per second (cfs);

Qor = is the discharge of overland or surface runoff in cfs;

DSor = is the dissolved solids concentration of the surface runoff in parts per million (ppm);

Qgw = is the ground-water discharge in cfs;

DSgw = is the dissolved solids concentration of ground-water discharge in ppm.

In the case where conductance of streamflow is considered, the following equations are used:

$$Q_g + Q_s = Q \quad \ldots (1)$$

$$C_g\ Q_g + C_s\ Q_s = CQ \quad \ldots (2)$$

where: Q_g, Q_s, and Q are ground-water discharge, surface runoff and total streamflow discharge in cfs;

C_g, C_s, and C are conductivity values of ground-water discharge, surface runoff and total streamflow discharge in micromhos.

If the three conductivity values C_g, C_s, and C and the total streamflow discharge Q are known, these two equations can be solved for Q_g, the ground-water discharge contribution as follows:

$$Q_g = Q\ (C - Cs)/(C_g - C_s) \qquad \ldots (3)$$

In order to determine the conductivity of ground-water discharge and surface runoff, samples are taken where the water in the stream is assumed to be composed of ground-water discharge only. The conductance of surface runoff is determined by sampling the creek water during a flood period.

DETERMINATION OF GROUND-WATER DISCHARGE TO WILMOT CREEK BASED ON HYDROGRAPH SEPARATION USING RECESSION FACTORS

Development of Recession Factors

A streamflow hydrograph represents a composite of discharges from different ground-water reservoirs upstream from the point of record, surface runoff and bank storage. An attempt was made to determine the ground-water discharge to Wilmot Creek by making use of streamflow data for the development of a recession curve.

The empirical approach developed by Barnes (1940) for hydrograph separation was used. Hydrograph recession factors were first developed for the 1965-1967 water-years data. Daily average recession discharges in cfs, for the downstream federal gauging station 2HD9 on Wilmot Creek, were plotted against the daily average discharges of the preceding day for those days not influenced by rain. The plots were undertaken for periods arbitrarily chosen as two days following a precipitation event. A recession factor was developed by deriving the slopes of the lines as shown in figures 4 and 5.

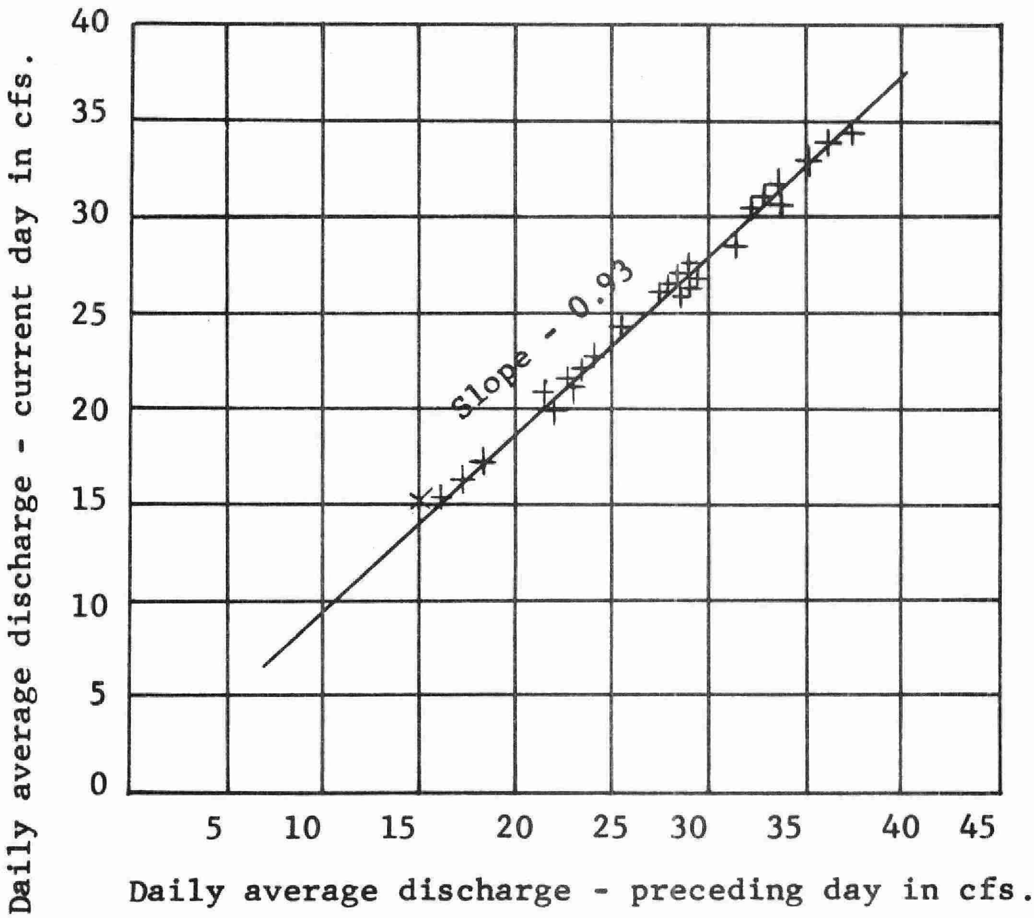


Figure 4. Daily average discharge (current day versus preceding day) of high flows in cfs at station 2HD9 in the Wilmot Creek basin.

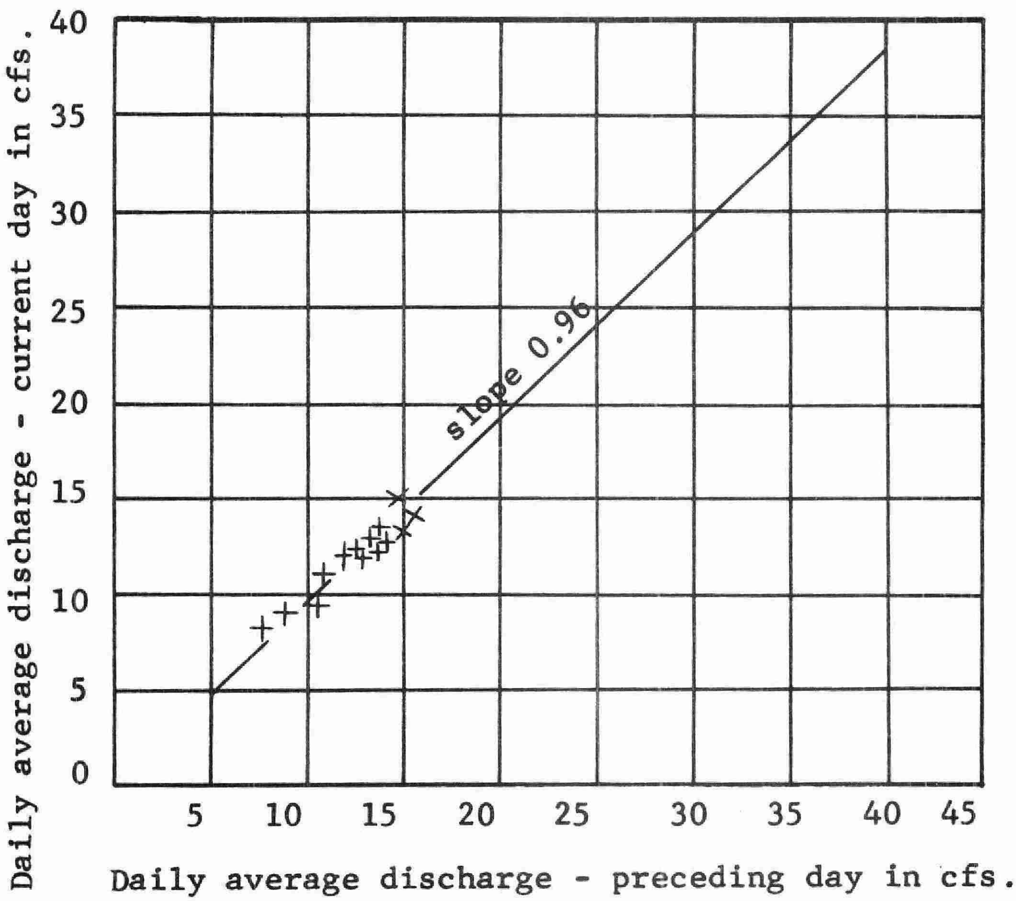


Figure 5. Daily average discharge (current day versus preceding day) of low flows in cfs at station 2HD9 in the Wilmot Creek basin.

The daily recession factors, as computed from these plottings, were found to be 0.93 for the high flows during the period March, April and May and 0.96 for low flows during the months of June, July, August, September, October and November. An average recession value of 0.94 was then drawn on the stream hydrograph on which total runoff was plotted on semilogarithmic paper, in the manner illustrated in Figure 6.

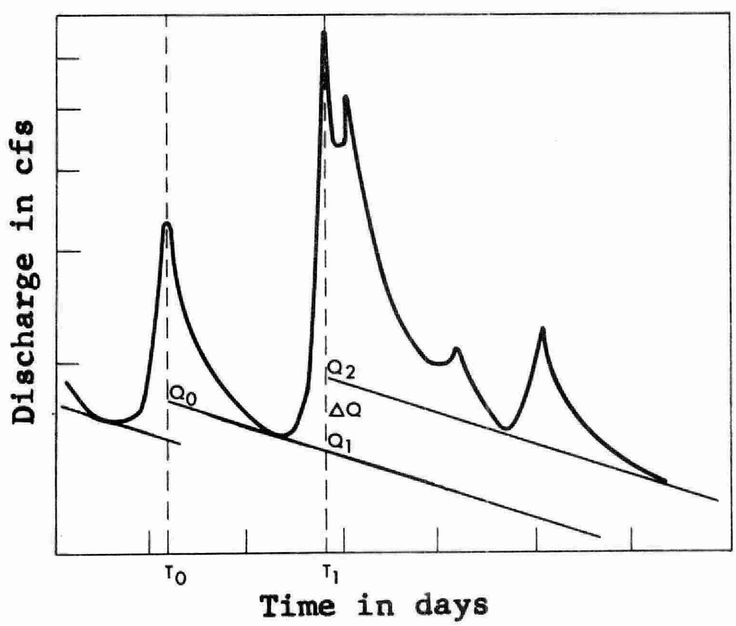


Figure 6. Variables used in determining increase in ground-water discharge ΔQ due to a corresponding rainfall event period.

The recession factor of 0.94 appeared to fit approximately the falling stages of the hydrograph throughout the time period 1965-1967.

An attempt was made to evaluate the yearly amount of ground-water discharge at the federal downstream gauging station 2HD9 in the Wilmot Creek basin. The ground-water discharge was calculated on a daily basis, assuming that the amount of flow beneath the recession line was composed of ground-water discharge and any amount of flow above the recession line was composed of surface runoff. It should be emphasized, however, that ground-water discharge, as derived from the graph, probably includes some flow from channel and bank storage. The daily ground-water discharges computed in this manner were then added to give the total yearly ground-water discharge.

Table 1 summarizes the yearly precipitation, as recorded from the climatological station at Orono, and the total discharge recorded for the federal downstream gauging station 2HD9. The surface runoff in Table 1 was computed by subtracting the yearly ground-water discharge computed by the recession method from the total streamflow discharge.

Table 1. Yearly Account of Hydrologic Budget Items for 1965-1967 Water Years in the Wilmot Creek Basin

Year	Precipitation (inches)	Total Discharge (inches)	Ground-Water Discharge (inches)	Surface Runoff (inches)
October, 1965 - September, 1966	31.37	10.91	5.59	5.32
October, 1966 - September, 1967	38.99	12.38	6.45	5.93

The increase in the yearly precipitation during the 1966-1967 water year, compared to 1965-1966, which amounted to 7.62 inches, resulted in an increased total discharge of 1.47 inches and caused about a 15 per cent increase in the calculated ground-water discharge. Such a small increase in ground-water discharge for the comparably larger amount of precipitation is assumed to be due to factors such as increased evapotranspiration and increased ground-water storage. A detailed analysis of these factors is beyond the scope of this report because of the lack of available hydrologic data.

Another relationship developed in this study defines the approximate increase in ground-water discharge during given 30-day periods versus monthly discharges.

Figure 6 illustrates the variables used in determining the increase in ground-water discharge, ΔQ, which is the vertical increment between Q_1 and Q_2 and is inferred to be due to rain during the period T_o to T_1. The total amounts of the ΔQ's for each month were then added together. The mean monthly increase in ground-water discharge in cfs was then plotted against the corresponding mean monthly discharge in cfs, as illustrated in Figure 7.

The data used to develop the relationship in Figure 7 were taken for the months of May, June, July, August and September for the water years 1965-1966 and 1966-1967. The data plotted show a wide variation of points for the same monthly periods for the two water years studied. Several factors were considered as causes for the wide scatter of points.

1. Variation in the distribution and intensity of precipitation over the basin during each month and from month to month.

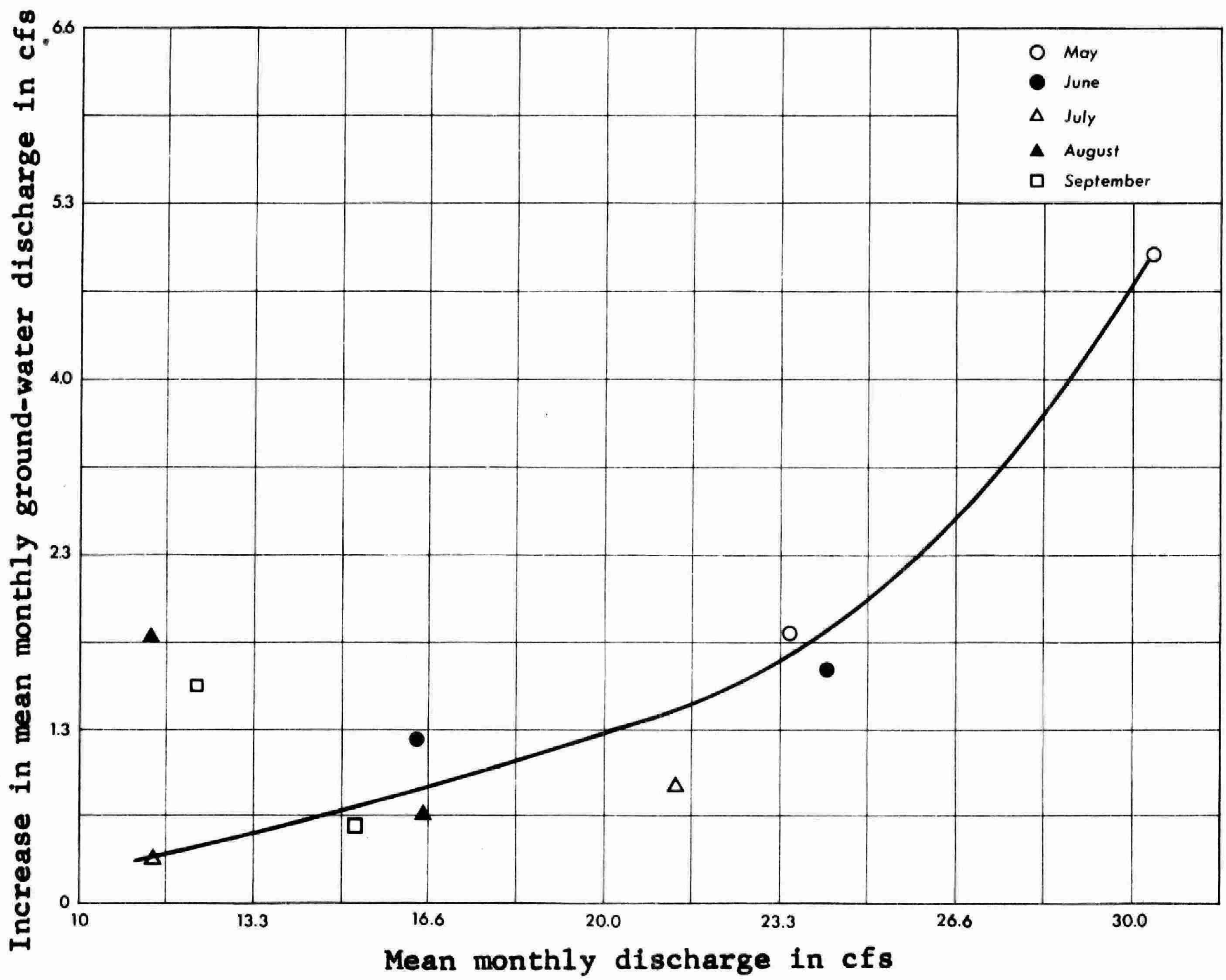


Figure 7. Relationship between monthly discharge and monthly increase in ground-water discharge at station 2HD9 in the Wilmot Creek basin (water years 1965 - 1967).

2. Variations in the ΔQ values as a result of the short period of record used to calculate the recession factors.

3. Variations in antecedent soil moisture conditions during the time periods selected.

4. Variations in evapotranspiration during the time periods selected.

5. Variations in ground-water levels during the time periods selected as a result of varying ground-water storage conditions.

From an examination of monthly precipitation records and observation-well hydrographs, it would appear that for some months, scatter of the points may be partially due to variations in the distribution and intensity of rainfall over the basin and to variations in the ground-water levels; however, it is believed that the major amount of scatter of the points is due mainly to antecedent soil moisture conditions and to variations in monthly evapotranspiration rates. The lack of data on these factors and limited streamflow data of only two water years, precluded further consideration in this analysis.

DETERMINATION OF GROUND-WATER DISCHARGE TO WILMOT CREEK USING CONDUCTIVITY MEASUREMENTS

Description of Study

Water samples were taken at three locations along Wilmot Creek on a monthly basis, over a period of about three years. The sampling points were taken in the vicinity of the stream gauging stations where continuous streamflow measurements were recorded. Chemical analyses of the samples were provided by the Ontario Water Resources Commission, Division of Laboratories. The locations of the three, stream-gauging stations are illustrated in Figure 8, and the data collected are given in appendixes 1, 2, and 3. The data were also plotted on a discharge versus conductivity graph and these resulted in seemingly unrelated points (Figure 9).

It is believed that the wide scatter of points is due in part to antecedent moisture conditions in the basin. For example, in summer, soil moisture conditions may be such that much of the rainfall is absorbed to replenish a deficiency in soil moisture and surface runoff may not be an important factor as a streamflow component. During this period, a high proportion of the stream discharge

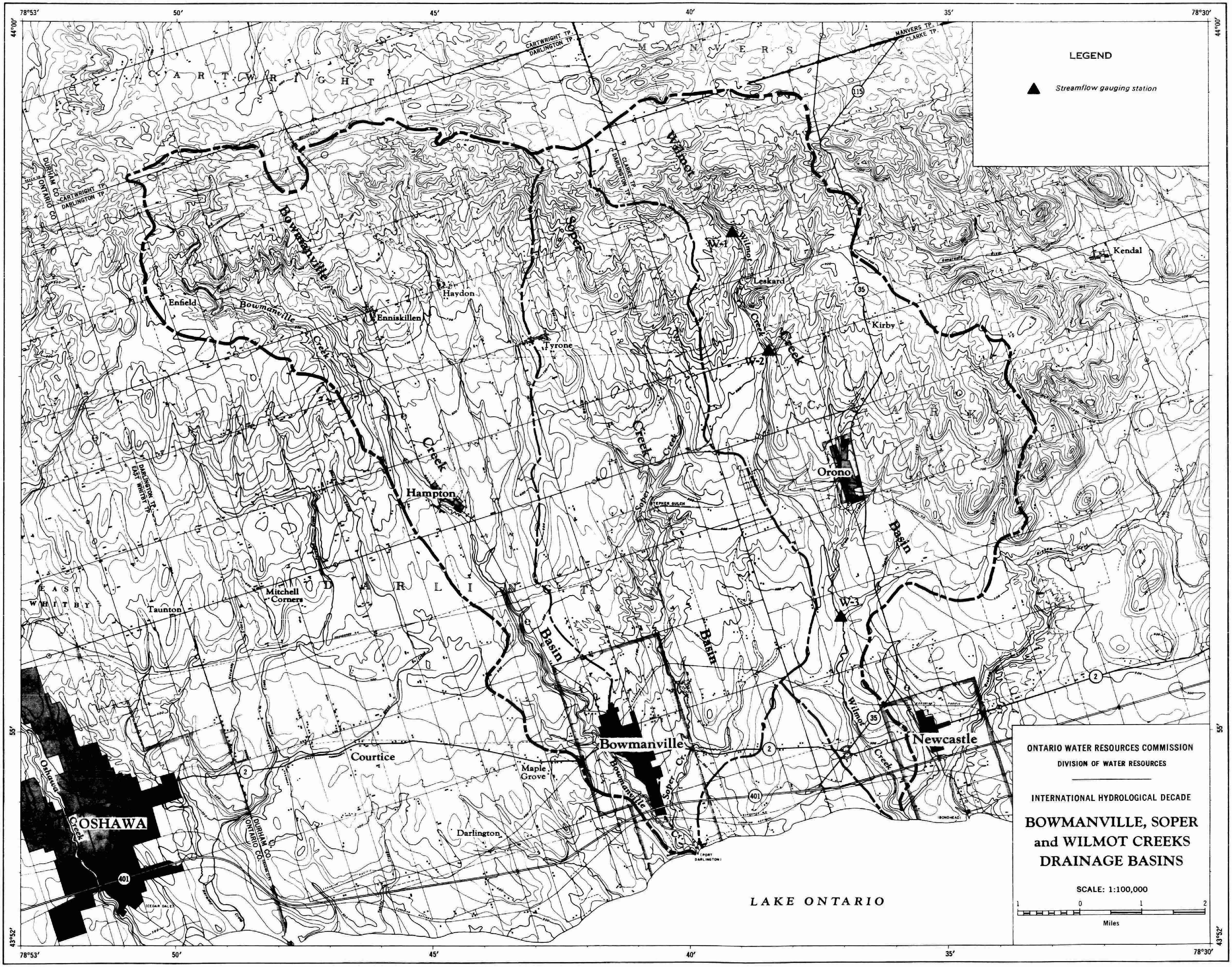
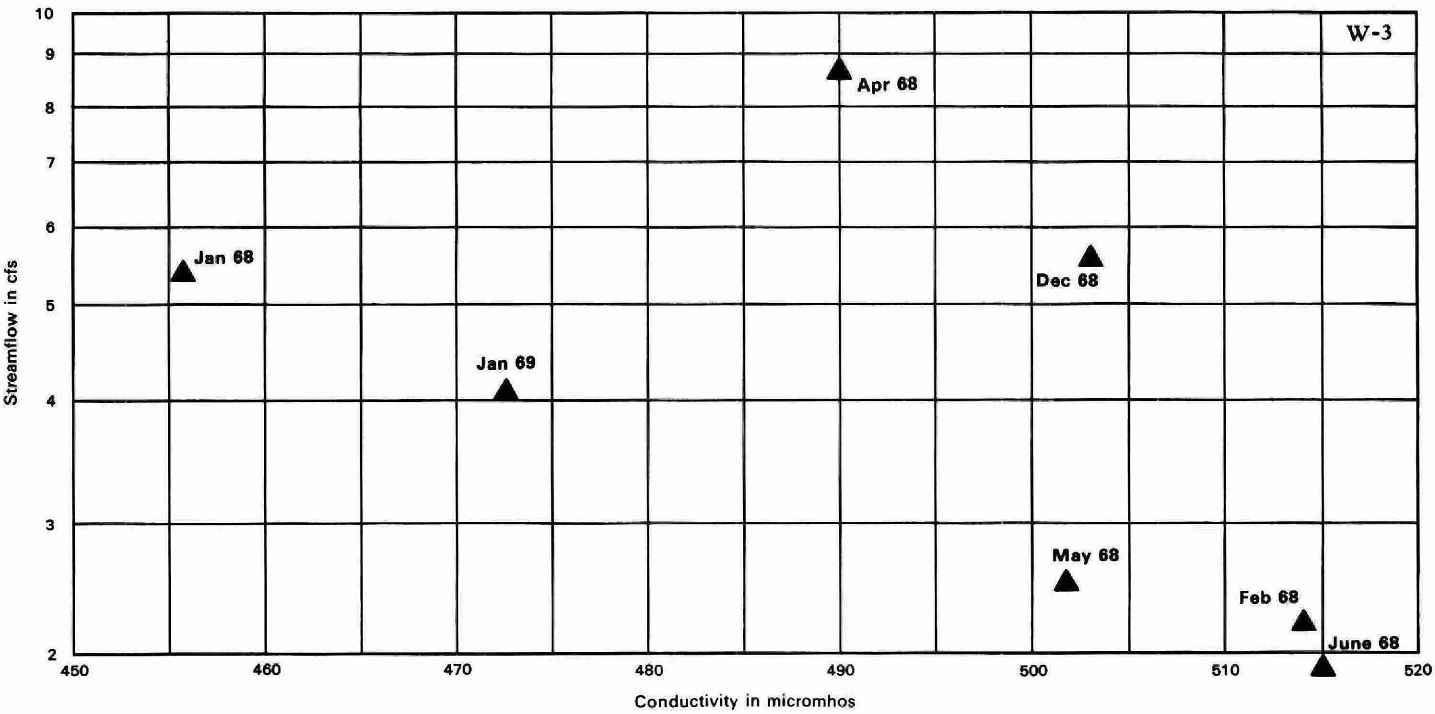
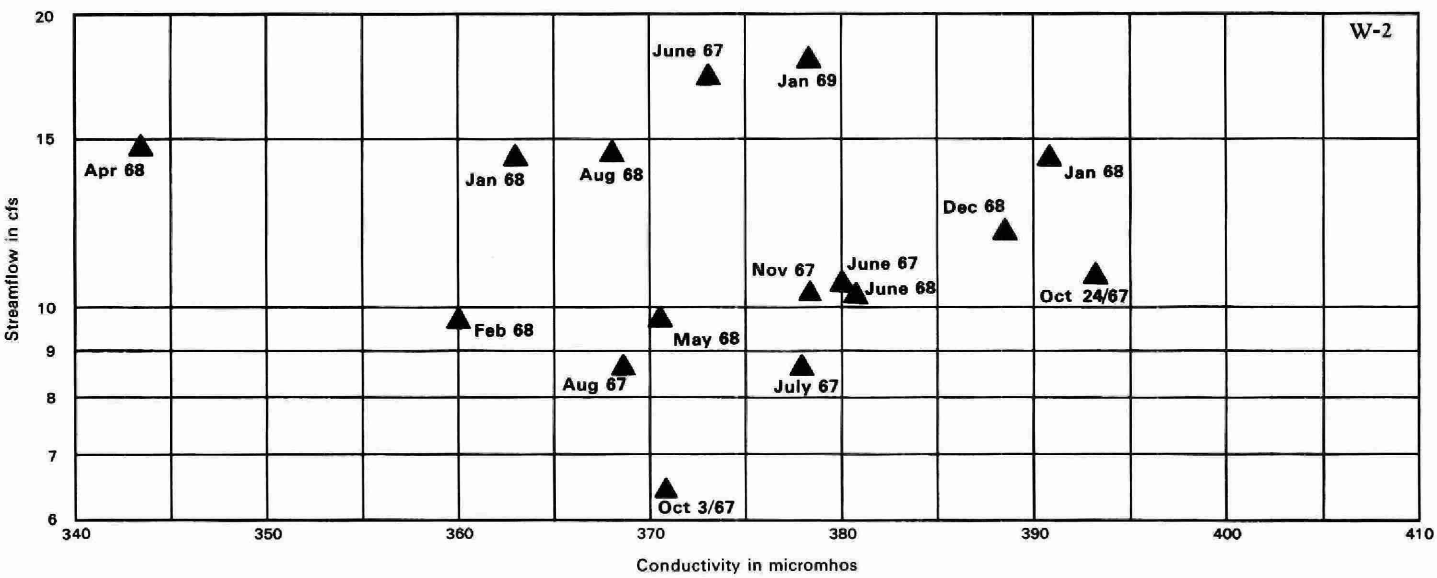


Figure 8. Location of streamflow stations used in the Wilmot Creek basin study.





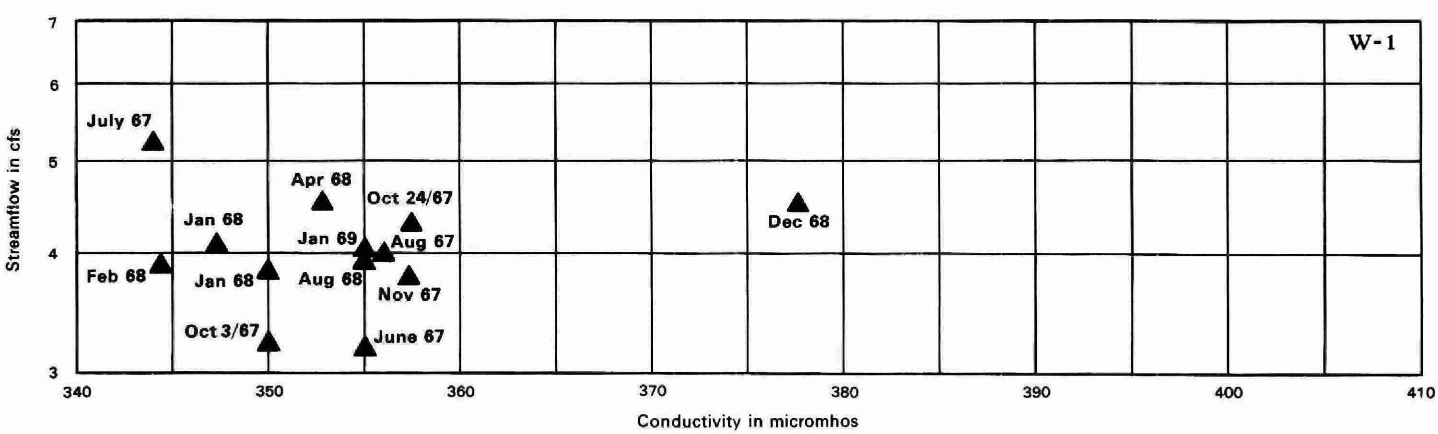


Figure 9. Relationship of conductivity in micromhos versus corresponding discharge at three points along Wilmot Creek.

may be derived almost solely from ground-water discharge. In the spring, however, the soil may be relatively saturated and surface runoff into the creek may become the dominant component of streamflow.

Seasonal and year-to-year variations in hydrologic conditions in the basin are illustrated in Figure 7. Average daily streamflow discharges during the July months for the water years October, 1965 - September, 1967 were about 11 cfs and 21 cfs; however, there did not appear to be any significant monthly increase in the ground-water discharge component of streamflow for these months. During the May months, average daily streamflow discharges were about 23 cfs and 30 cfs, and there were significant increases in the ground-water discharge component.

It is evident that the ion concentration of the water in Wilmot Creek will change seasonally throughout the water year and from year-to-year.

The Chemical Change in Stream Quality during a Specific Flood

The partial influence of the individual stage of a specific flood on the amount of the dissolved solids content of stream water can be investigated during a

flood cycle. Such a study has been conducted in the Wilmot Creek basin and is discussed in detail.

In order to evaluate the chemical changes during a flood cycle, samples of stream water were collected during a rainfall event. The conductivity of stream water was measured for a period of four days, during the rising and falling stages of the streamflow hydrograph, for a rainfall event which lasted for three days from April 22 to 24, 1969, over varying sampling intervals from two to eight hours. The conductivity of the stream water was obtained by a battery-operated conductivity meter. The meter was connected to the conductivity cell by a service cable and the cell was placed in the creek. All the data were adjusted to 25^{o}C by a temperature compensator within the meter. The data gathered from the study are shown in Figure 10, as conductivity in micromhos versus streamflow discharge in cfs.

The graph indicates that the relationship between changes in discharge and conductivity varies during different parts of the flood event. The single flood cycle can be divided into several phases. The first phase is that part of the curve from A to B, where point A represents the conductivity under baseflow conditions in the stream,

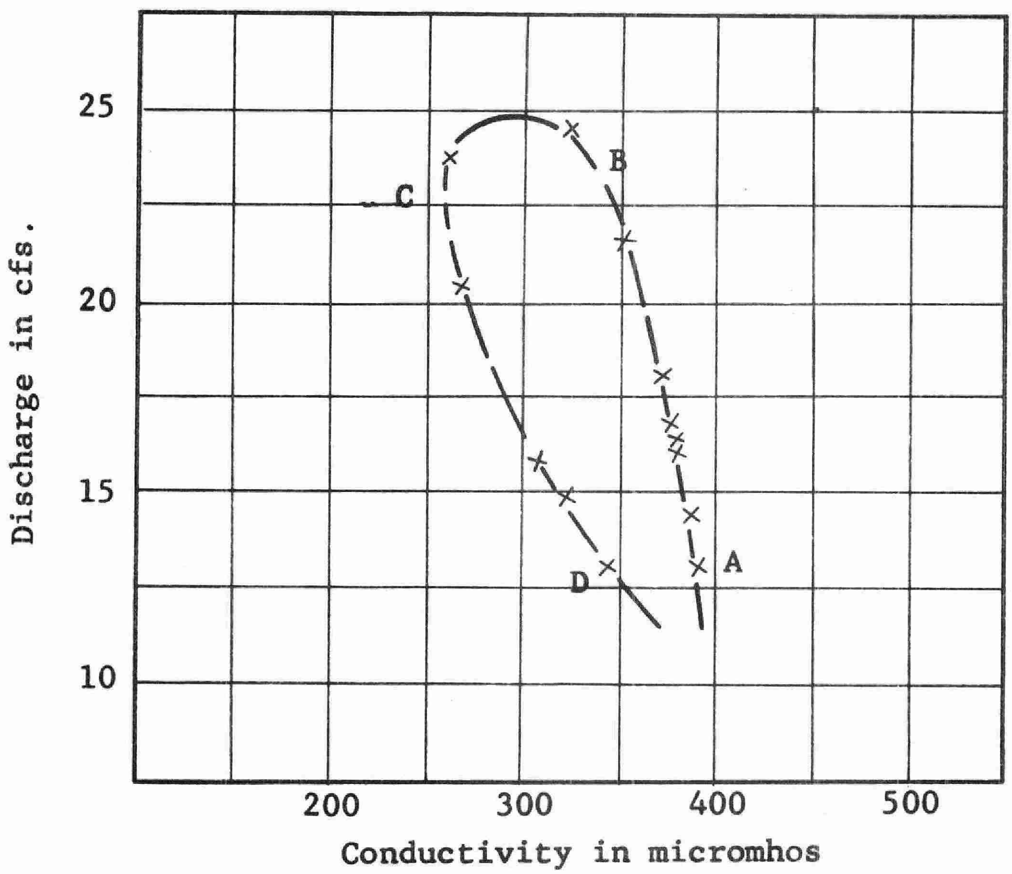


Figure 10. Cyclic variations between streamflow discharge and conductivity at stream gauging station W-2 in the Wilmot Creek basin for a rainfall event period.

prior to the flood event. During this phase, the conductivity of water decreases approximately 40 per cent of its range of fluctuation as streamflow discharge increases rapidly. Although a large proportion of the water coming into the stream during this phase is composed of surface runoff that has only been in contact with the soil in the unsaturated zone, the expected large decrease in conductivity is masked by a significant increase in ground-water discharge, probably due to prevailing spring ground-water storage conditions in the basin. During months of low ground-water discharge, more drastic decreases in conductivity could be expected for the first part of the flood cycle.

The second phase, from B to C, indicates a significant decrease in conductance with little change in streamflow discharge. The water coming into the stream during this phase has a decreased amount of soluble material and it is presumed that at the time the stream is near peak discharge, water is moving from the stream into the banks. Thus in effect, ground-water discharge is retarded and as a result the ion concentration of stream water decreases.

The third phase, C to D, is marked by a decrease in streamflow discharge and an increase in conductance. During the falling stage of streamflow, water stored

temporarily as bank storage moves once more into the stream and ground-water discharge becomes prominent. Because ground water contains a higher concentration of dissolved solids, streamflow becomes progressively higher in ion concentration.

From the preceding observations made during a rainfall event, hydrograph separation by the conductance method appears to be a workable technique; however, reasonable components are required in order to use the Kunkle method with a high degree of accuracy. It should be emphasized, however, that although such a curve, as illustrated in Figure 10, can be developed in as little as four days in a small area like the Wilmot Creek basin, it is believed that in some other basins such a cyclical curve could take a longer time to develop. The factors determining the time to establish the cyclical curve will depend on the geohydrologic conditions of the basin. In the case where long periods are required to develop the curve, its full development could possibly be interrupted by the occurrence of another flood event. It is also believed that small precipitation events could pass undetected by this method because of insufficient recharge to cause a marked influence on the conductivity of the stream.

RECOMMENDATIONS FOR FUTURE STUDY

A continuous conductivity recorder should be installed in the vicinity of one of the stream gauging stations in the Bowmanville, Soper and Wilmot creeks basin in an effort to delineate with more accuracy the ground-water discharge component of streamflow and hopefully allow the use of the Kunkle method for this purpose.

A line of about six to eight observation wells, each about 30 feet apart, should be drilled to the water table in a straight line away from the creek in the same area where the conductivity recorder is to be installed. The objectives of these shallow wells will be to give a better insight into bank storage problems and water-table gradient changes in the vicinity of the creek. It is suspected that at peak stream discharge, ground-water discharge into the creek is retarded by bank storage together with gradient changes developing in the vicinity of the creek. As the river stage falls gradually, ground-water discharge, which may have been retarded temporarily, begins to discharge once more into the creek. These dynamic factors which develop in the vicinity of the creek should be investigated in the future to determine their influence on the conductivity of streamflow.

As there is no exact technique available for distinguishing ground-water discharge and surface runoff, present techniques cannot be evaluated, except by mutual comparison of the methods available. Although it is virtually impossible to separate surface runoff from ground-water discharge on a physical basis, for practical purposes, flows which run quickly from watersheds and flows which are delayed or well-controlled, should be classified. The simple terms of quick and delayed flows are useful, rather than the usual direct runoff and baseflow, to avoid confusion with the variable definitions and techniques associated with the latter terms as discussed earlier.

SUMMARY

The study conducted on hydrograph separation, using the empirical method in which the daily average flow was plotted against the preceding daily discharge for those days not influenced by precipitation, was evaluated and recession factors of 0.93 and 0.96 were found for high and low flows in Wilmot Creek. The amount of ground water discharged to the creek was estimated by applying the average recession factor to the stream hydrograph plotted on semilogarithmic paper. The slope of the recession curve appeared to fit approximately the latter part of the falling stage of the stream hydrograph. The portion of the discharge beneath the recession line was considered to be ground-water discharge.

The yearly ground-water discharge for the Wilmot Creek basin above streamflow station 2HD9 was found to be 5.59 inches for a yearly precipitation of 31.37 inches during the water year 1965-1966. The increase in the yearly precipitation of 7.62 inches during water year 1966-1967 increased the calculated ground-water discharge by only 0.86 inches.

A second relationship investigated defined the monthly increase in ground-water discharge versus monthly runoff. The data plotted showed a wide scatter of points.

It is believed that the significant scatter of points is due mainly to variations in antecedent soil moisture conditions.

The conductance method was evaluated as a technique for hydrograph separation. No useful relation between streamflow and conductivity could be detected for samples collected on a monthly basis during the period June, 1967, to January, 1969. A loop-like relation was found between stream discharge and conductivity during a three-day storm event from April 22 to 24; this relation can be interpreted as due to changes in amounts of direct runoff due to precipitation and amounts of ground-water discharge caused by variations in water levels in the stream and in the aquifers. The collection of more conductivity data is warranted in an effort to establish the usefulness of the conductivity method for separating direct runoff from ground-water discharge in the Wilmot Creek basin.

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APPENDIX 1

Chemical Analyses of Stream Water at Gauging Station W-1 in the Wilmot Creek Basin

Appendix 1

Chemical Analyses of Stream Water at

Gauging Station W-1 in the

Wilmot Creek Basin

Date	IONIC CONCENTRATIONS IN PARTS PER MILLION						Conductivity (micromhos)	Stream-flow (cfs)
	Calcium as Ca	Magnesium as Mg	Potasium + Sodium as K + Na	Chloride as Cl	Sulphate as SO_4	Bicarbonate as $CaCO_3$		
June 13/67							355	3.26
July 12/67							344	5.27
August 10/67							356	4.00
October 4/67							350	3.29
October 25/67							357	4.38
November 29/67							357	3.80
January 10/68	58	11	2.9	2	22	168	350	3.84
January 17/68	60	10	2.8	2	20	171	347	4.11
February 16/68						170	344	3.94
April 3/68	58	11	2.8	2	17	168	353	4.58
August 20/68	60	10	3.2	2	23	171	355	3.94 e
December 3/68	62	11	4.1	4	15	172	377	4.58 e
January 21/69	52	16	4.2	2	17	171	355	3.98

e - estimated

APPENDIX 2

Chemical Analyses of Stream Water at
Gauging Station W-2 in the
Wilmot Creek Basin

Appendix 2

Chemical Analyses of Stream Water at

Gauging Station W-2 in the

Wilmot Creek Basin

Date	IONIC CONCENTRATIONS IN PARTS PER MILLION						Conductivity (micromhos)	Stream-flow (cfs)
	Calcium as Ca	Magnesium as Mg	Potasium + Sodium as K + Na	Chloride as Cl	Sulphate as SO_4	Bicarbonate as $CaCO_3$		
June 8/67							373	15.50
June 29/67							380	10.91
July 12/67							377	8.78
August 30/67							369	8.83
October 4/67							371	6.49
October 26/67							393	11.38
November 29/67							378	10.35
January 9/68	51	18	3.8	4	22	182	391	14.33
January 30/68	66	7	3.9	4	21	171	363	14.62
February 28/68				3		179	360	9.90
April 3/68	66	9	4.0	4	16	190	343	14.65
May 27/68				4		183	371	9.84
June 24/68				4		185	381	10.13
August 20/68	60	11	4.2	4	23	172	368	14.30
December 3/68	69	11	4.0	4	17	183	389	12.47
January 22/69	65	13	6.2	4	17	183	378	15.66

APPENDIX 3

Chemical Analyses of Stream Water at Gauging Station W-3 in the Wilmot Creek Basin

Appendix 3

Chemical Analyses of Stream Water at

Gauging Station W-3 in the

Wilmot Creek Basin

Date	IONIC CONCENTRATIONS IN PARTS PER MILLION						Conductivity (micromhos)	Stream-flow (cfs)
	Calcium as Ca	Magnesium as Mg	Potassium + Sodium as K + Na	Chloride as Cl	Sulphate as SO_4	Bicarbonate as $CaCO_3$		
January 30/68	77	11	7.1	10	34	200	456	5.47
February 29/68				13		238	514	2.28
April 3/68	93	5	5.6	8	23	238	490	8.88
May 27/68				8		232	502	2.54
June 24/68				10		233	515	1.88
December 3/68	101	8	6.8	8	36	231	503	5.58
January 22/69	83	10	7.9	10	26	204	473	4.03